$$G = \frac{4}{3}\sqrt{2\pi}.R^3\sqrt{\rho_1}\frac{p'-p''}{L},$$

where R is the radius of the tube, L its length, and p' and p'' the pressures at the ends. By a series of experiments with a tube, the length of which was 2·00 cm., the radius 0·00333 cm., the proportions between the measured values and those calculated from this formula were found to be, for hydrogen, 1·04; oxygen, 1·01; carbonic acid, 1·01.

The formula will, however, only apply correctly when the radius of the tube is small compared with the mean free path. With increasing pressure $\frac{p'+p''}{2}$ (decreasing mean free path), the gas flow of a given value for $p'-p''$ decreases to a minimum, and afterwards increases in order to approach the value which it should have according to Poiseuille's well-known law. That this must be the case may easily be inferred from the kinetic gas theory in connection with the above-mentioned theory as to the interaction between gas molecules and a wall.

MARTIN KNUDSEN.

The University, Copenhagen.

The Germ-layer Theory.

THE germ-layer theory as stated on p. 428 of NATURE (June 10) by Mr. Stanley Gardiner appears in a rather extreme form. Probably all will agree that, not only the germ-layer theory, but every theory of development, presupposes a certain definiteness in structure of germ cells. But if that much is granted, it is not necessary to suppose that the differentiation of protoplasm has proceeded at so early a stage to such an extent as to preclude absolutely the possibility of protoplasm, which has been so far misplaced by experiment as to find itself in a new environment, responding to the influences of the new environment and so developing along a path it would not have followed had the experiment not been performed.

It seems difficult to comprehend what reason can be assigned for regarding those organs of the early phase of the life-cycle which we call germinal layers as being less capable of showing homology than the organs of later phases which we speak of as adult.

Surely the biological principles—whatever they may be—must apply equally throughout all periods of the life-cycle.

The argument from regeneration is hardly conclusive, because one essential of regeneration and budding seems to be the regression of differentiated protoplasm into undifferentiated protoplasm (or, at any rate, the origin in some way or other of an undifferentiated cell mass), that is to say, a regression to a state equivalent to a segmenting egg, namely, a state really prior to that of germ-layer formation.

Finally, it must be remembered that visible differences and resemblances are much less obvious in these early phases of the life-cycle than later, and that the difficulty of observation, owing to the minute size of the objects, is so great that errors of observation, which delay correct interpretations, are far more frequent than is the case with work upon the grosser phases of the life-cycle.

It cannot be conceded that the "anomalies in the formation of the layers in vertebrates" which are "patent to every student" are all capable of substantiation.

Grantchester, June 15. RIC. ASSHETON.

The Pollination of the Primrose.

IT appears that in a previous note on this subject (NATURE, June 17, p. 457) clearness may have been sacrificed to brevity. It is not meant that humming-bird and bee hawk-moths can be regarded as usual or frequent agents in the pollination of the primrose. They are mentioned in proof that some moths do, now and then, visit the flowers, and may presumably aid in their cross-pollination. There can be little doubt, however, that the humble-bee is herein the chief agent, and in this district, I should say, more particularly *Bombus hortorum*.

W. E. HART.

Kilderry, Londonderry, June 19.

FROST AND ICE CRYSTALS.[1]

DURING the past quarter of a century Mr. Wilson J. Bentley has devoted himself with a patient industry deserving of all praise to securing permanent records of the multitudinous forms assumed by water in its crystallised condition. The work has been executed at his home, a farmhouse, situated sixteen miles east-north-east of Burlington, Vermont, near the Canadian border, at an altitude of 1500 feet above sea-level, where the low temperatures experienced every winter are very favourable for the study of these forms. Seven years ago we directed attention (NATURE, 1902, vol. lxv., pp. 264–6) to his beautiful series of photomicrographs of snow crystals; a selection of them was reproduced in the *U.S. Monthly Weather Review*, and was accompanied by a paper in which Mr. Bentley described the methods used for obtaining the photographs, and the facts that could be established from a study of the almost bewildering variety of the forms represented. At the same time, but mainly during the subsequent years, Mr. Bentley has been further engaged in preparing a companion and complementary series of frost and ice crystals, *i.e.* the forms assumed by water that has crystallised immediately upon the surface of the earth. A large number of different types were reproduced in successive numbers of the *Monthly Weather Review* from August to December, 1907, and Mr. Bentley again contributes a description of the apparatus used, and full details with regard to the circumstances under which the several pictures were obtained.

Nearly the whole of the present series represents crystals that were formed during the winters of 1904–5, 1905–6, and 1906–7. For several reasons fewer difficulties were experienced in obtaining photographs of these crystals than was the case in the investigation of snow crystals; they could invariably be photographed in the positions in which they were found, and since, owing to the greater duration of growth, their size was usually much larger, smaller magnifications were required, and, indeed, in pictures of groups of crystals actual reductions were called for. The apparatus used was consequently simpler in character. For the majority of the photographs, in which the magnification did not exceed eight diameters, an ordinary portrait-lens was used in a camera which was fitted with a home-made extension arrangement, and the crystals were illuminated obliquely. For higher magnifications a microscope-objective, of ¾- or ½-inch focal length, was employed, and the illumination was direct. The second method, which was required for the minute flakes deposited on windows, entailed more trouble in manipulation, because, while the camera was indoors, the diaphragm for cutting off all but direct light was on the other side of the window, and had, of course, to be adjusted for each position of the camera.

The series is divided into three principal groups—hoar-frost, window-crystallisation, and ice—a few sections dealing with hail being appended, and for convenience each group is split up into divisions and subdivisions, according to the shape or the grouping of the crystals. The hoar-frost group is divided into two main divisions—tabular and columnar—but the distinction is apparently one of degree only, and cannot be pressed. We have selected as an illustration of this group a beautiful example of the "open branch or tree-like" structure (Fig. 1). It will be noticed that the stems broaden out into well-developed plates at their terminations. The study of the crystals deposited on windows obviously admits of greater ease of observation, and, since the conditions of the atmo-

[1] "Studies of Frost and Ice Crystals." By Wilson J. Bentley. Pp. 22; with 273 figures on 31 plates. (Reprinted from the *Monthly Weather Review*, 1907.)

sphere obtaining within a dwelling provide more extensive ranges of temperature and humidity, greater diversity in the type of crystals is to be expected; it is not surprising, therefore, to find that three-fourths of the illustrations record forms that appeared on windows. This group is, of course, distinguished from the frost and ice groups, not by any essential difference in the characters of the crystals, but merely by their site. Crystallisation which has resulted from sublimation shows greater variety, and by far the larger number of examples are devoted to window-frost; but the window-ice forms, which occur in comparatively mild weather when a film of dew has first condensed on the surface of the glass, are not without interest. Mr. Bentley has greatly enhanced the value of the series by noting for each example the temperature out of doors and the temperature and degree of humidity within doors. Fig. 2 represents a beautiful example of "branching" window-frost. Its symmetry has been slightly affected by the disposition of the surrounding crystals, one arm exceeding the others in size; indeed, the limitations set by the chance position of adjacent crystals rarely permit of the almost perfect symmetry characteristic of snow-crystals. These fern- or tree-like forms are frequently seen on the windows of both warm and cold rooms, but are most common in unheated rooms of which the temperature ranges from 32° to 5° F. (0° to −15° C.) and the percentage of humidity from 55 to 70. Fig. 3 illustrates a nearly perfect example of the stelliform of window-frost, a slow-growing type that occurs only in cold weather when the temperature indoors is as low as 20° F. (−6·6° C.). The two crystals which we illustrate are fairly typical of the delicate crystallisation that embellishes the windows in frosty weather. Even in photographs their beauty is evident, but, to quote Mr. Bentley, "Only those who have seen frosted window-panes lit up by a bright winter moon, or seen them flash and sparkle under the rays of a winter sun, have seen the full beauty of the frost." Ice, though in appearance a uniform, solid mass, is really composed by the accretion of innumerable discrete crystals. The separate individuals are generally indistinguishable in the mass, but certain of them may be brought to light by slight heating—such as the warmth due to the sun's rays.

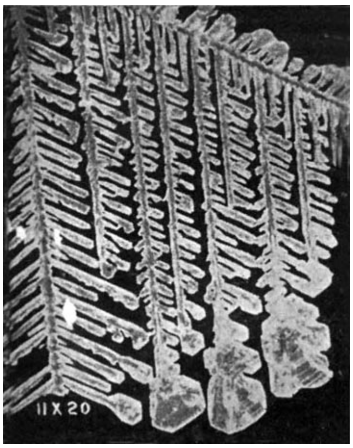


FIG. 1.—Tabular hoarfrost.

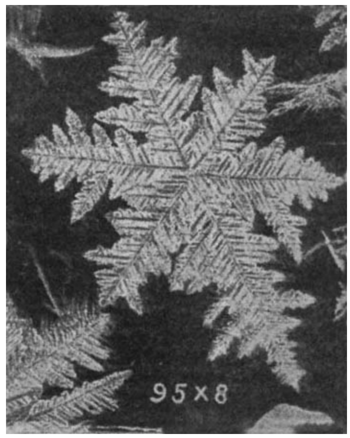


FIG. 2.—"Branching" window-frost.

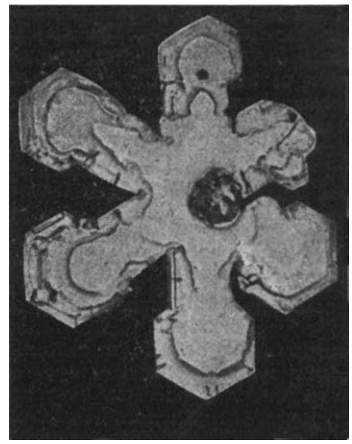


FIG. 3.—Stelliform window-frost.

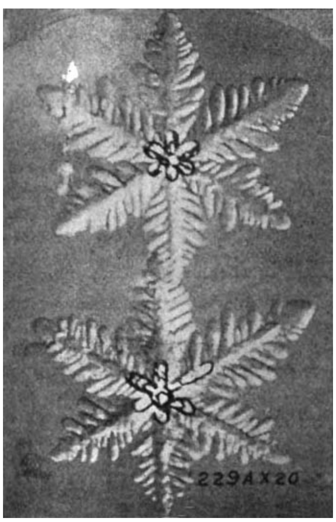


FIG. 4.—"Ice-flowers" in solid ice.

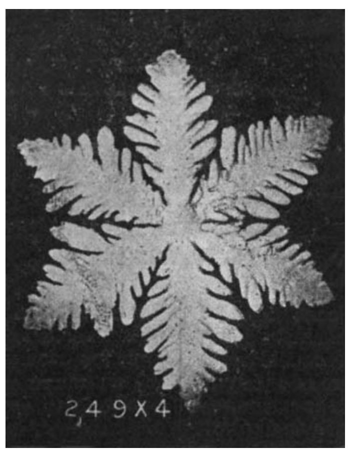


FIG. 5.—"Ice-flower" on freezing water.

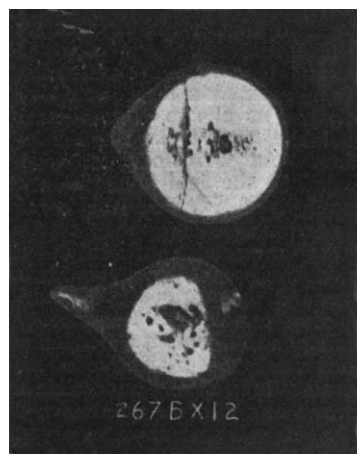


FIG. 6.—Pear-shaped hailstone.

Mr. Bentley includes in his series reproductions of three admirable photographs—one is shown in Fig. 4—of "ice-flowers," Tyndall's appropriate term for them, embedded in solid ice; these particular photographs

were taken by Prof. Benjamin W. Snow, of Wisconsin University. One of the more elaborate ice-flowers that form on the surface of freezing water is illustrated in Fig. 5. Mr. Bentley closes his paper with an interesting discussion of the occurrence and cause of hail in both summer and winter, and of the structure of hailstones. Hailstones have various shapes; they are commonly round, but egg- and pear-shapes are not rare. They invariably contain air-tubes and bubbles; a typical arrangement, shown by a stone which fell in the winter of 1906–7, is depicted in Fig. 6.

Thanks to Mr. Bentley, it is now possible to compare and study every variety of snow, frost, and ice crystals, and the way is clear for the next step, viz. to determine the factors and the conditions governing the several forms. It is strange how little is precisely known of the crystalline form of what in its three different phases is one of the most familiar, necessary, and conspicuous substances in nature. The system is undoubtedly hexagonal, possibly hemimorphic; but the axial ratios quoted in mineralogical text-books are based merely upon exceedingly rough observations made by Nordenskiöld on some snowflakes which fell during the severe winter of 1860. So far as we are aware, no crystal of water has yet been measured with a goniometer, and there is an opportunity for a crystallographer zealous enough to invade a refrigerator for the purpose of measuring a crystal grown under conditions that have been kept as uniform and as favourable as possible. In the course of his paper Mr. Bentley comments upon the curious changes that have often occurred during the growth of certain of the crystals. For instance, in Fig. 1 the crystals were at first narrow, but afterwards became broad and well-defined. This phenomenon may probably be explained as due to a change from the labile to the metastable condition. As Principal Miers has shown, in the labile condition the growth is rapid, and the crystals are narrow and ill-formed; whereas in the metastable condition the growth is slow, and the crystals are large and well-formed. We anticipate that experiments conducted under conditions of humidity and temperature which were accurately determined would be productive of results of considerable interest. It is clearly impossible to be sure of the temperature of a window even when those of the room and of the outer air are known; a slight gust of wind might cause a lowering of some degrees. G. F. H. S.

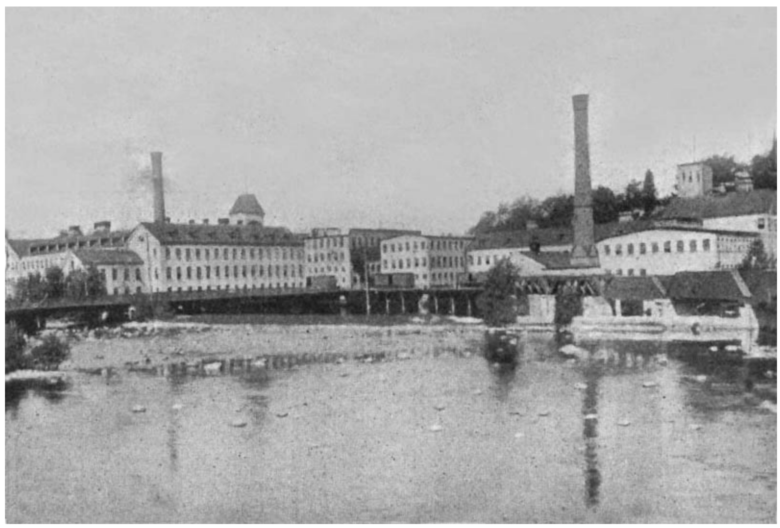
WATER POWER IN THE UNITED STATES.

IN many of the States of North America water is regarded as one of the most valuable of the natural resources. Unlike timber or minerals, it is inexhaustible, and so long as the rain continues to fall the water resources are being continually replenished. This fact has been more fully realised since the transmission of power to long distances has become practicable owing to the development of electricity.

The State of Wisconsin is probably as favourably situated as any of the States with reference to its water power. Realising this fact, the legislature, in conjunction with the Geological Department of the United States, undertook the surveying of the rivers of the State and the investigation of their adaptability to the generation of power. Six hundred miles of rivers have already been surveyed, and the results recorded in a report issued by the Wisconsin Geological and Natural History Department.

This report states that at the time of its publication water-power installations to the extent of 130,000 horse-power had been developed, this being only a small instalment of the resources of the rivers.

The average grade of the water surface of the rivers surveyed varies from 3 to 8 feet per mile. The average yearly rainfall is 32·30 inches. Dry periods occur in cycles of about twenty-five years, when the rainfall drops to 24·20 inches, and exceptionally dry periods occur about once in fifty years, when the lowest rainfall recorded was 13·50 inches. Owing to the storage effects of lakes and swamps, the low-water run-off is as high as 0·3 to 0·8 foot per square mile of the drainage area. The cutting down of the forests is, however, having a considerable effect on the yield of the rainfall; where clearances have been carried out the rain being less absorbed by the soil and the water reaching the streams more quickly.



The Fox River Paper Company's Mills, Appleton, Wis. Middle Dam.

The most important purposes to which the water power is applied are the paper and woollen mills and for electric light and traction. An example of the extended use of water power for generating electricity is to be found in the works of the small town of Kilbourn, on the Wisconsin River, and its distribution to places 50 miles distant. On the Saint Croix River, where a fall of 50 feet is available, the power developed is equal to 27,000 horse-power, and the transmission extends to a distance of 40 miles. The instalment on the Saint Louis River, when fully developed, will be equal to 200,000 horse-power, and the distance of transmission 75 miles. This instalment, when in full working order, will only be second to the great hydraulic plants at Niagara. On the Fox River there are three dams, and water power is supplied to a large number of paper and pulp factories, and also for factories and electric light and traction, the aggregate power being equal to 35,000 horse-power. The illustration, taken from the report of the Wisconsin Geological Department, gives some idea as to the extent of the factories the works of which are actuated by water power.